Journal of Economic Behavior & Organization 131 (2016) 218–242

Journal of Economic Behavior & Organization

journal homepage: www.elsevier.com/locate/jebo

Invalid but infringed? An analysis of the bifurcated patent litigation system☆

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ARTICLE INFO

Article history:
Received 17 October 2015
Received in revised form 9 July 2016
Accepted 13 August 2016
Available online 30 August 2016

Keywords:
Litigation
Patents
Bifurcation

ABSTRACT

In bifurcated patent litigation systems, claims of infringement and validity of a patent are decided independently of each other in separate court proceedings at different courts. In non-bifurcated systems, infringement and validity are decided jointly in the same proceedings at a single court. We build a model that shows the key trade-off between bifurcated and non-bifurcated systems and how it affects the incentives of plaintiffs and defendants in patent infringement cases. Using detailed data on patent litigation cases in Germany (bifurcated) and the U.K. (non-bifurcated), we show that bifurcation creates situations in which a patent is held infringed that is subsequently invalidated. We also show that having to challenge a patent's validity in separate court proceedings under bifurcation implies that alleged infringers are less likely to do so. We find this to apply in particular to more resource-constrained alleged infringers. Finally, we find parties to be more likely to settle in a bifurcated system.

1. Introduction

Patents are probabilistic property rights: there exists inherent uncertainty regarding a patent's validity and scope (Lemley and Shapiro, 2005). Although patents are granted by patent offices only after substantive examination, there is no guarantee

☆ We acknowledge financial support for the creation of the dataset used in this research by the ZEW SEEK 'Patent Litigation in Europe' project. Dietmar Harhoff acknowledges support from the DFG Collaborative Research Program SFB/TR 15 (Project C2). We thank Max Ernicke and Dieter Stauder for advice on the legal aspects of this study. We are particularly grateful to the editor, Thomas Gresik, and two referees for their helpful comments that have greatly improved the paper. We also thank Christoph Ann, Deepak Hedge, Filipe Fischmann, Annette Kur, Brian Love, Malwina Mejer, Petra Moser and Roberto Romandini for helpful comments. Christian Helmers thanks various lawyers at the JurisTisch for generously sharing their views on the German patent litigation system. The paper was presented at the 2012 Patstat Conference in Paris, the 5th ZEW/MaCCI Conference on the Economics of Innovation and Patenting, a seminar organized by the U.K. Intellectual Property Office, the IPSC 2014 at Berkeley, the Munich Conference on Innovation and Competition 2014, the 9th Annual Conference of the EPIP Association, the 41st Annual Conference of the EARIE 2014, the 2nd International Workshop on Economic Analysis of Litigation, the 27th Annual Meeting of the American Law and Economics Association, and a seminar at Santa Clara University.

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http://dx.doi.org/10.1016/j.jebo.2016.08.005

that a granted patent is in fact valid.[1] We show that the uncertainty that surrounds the validity of patents has important effects on patent enforcement and hence on the functioning of the patent system as a whole.

In patent litigation, patent holders allege the infringement of their patent right while defendants can deny infringement and challenge the validity of the patent in question. In many legal systems, such as the U.K., Italy, or Switzerland, the infringement and validity claims are decided simultaneously in the same court proceedings where the invalidation of a patent renders infringement impossible. In many other jurisdictions, including the U.S., Germany, and China, there is some separation of patent infringement and validity proceedings – so-called bifurcation.[2] The purpose of this paper is to analyze the effect of bifurcation on litigation behavior and outcomes.

Using detailed case-level data from German courts where infringement and validity are separated into independent proceedings, we show that in practice the decision on infringement is often made and enforced before validity has been determined under the presumption that granted patents are indeed valid. We show that this leads to situations in which a patent is held infringed that is subsequently invalidated. Our data on infringement and invalidity proceedings in Germany for 2000 to 2008 reveal that 12% of infringement cases with parallel invalidity proceedings (41% if we focus on cases without settlements) produce divergent, i.e., 'invalid but infringed', decisions (for examples see Table A-1 in the online appendix). Our analysis also shows that the length of this *injunction gap* is substantial. In cases where validity was challenged in court, the infringement decision was on average enforceable for more than a year before the patent was invalidated in first instance.

We build a theoretical model that illustrates the key trade-offs between bifurcated and non-bifurcated systems. First, our model incorporates the possibility of an injunction gap in the bifurcated system. In addition, challenging a patent's validity requires additional costs in the bifurcated system compared to non-bifurcated systems because validity has to be challenged in separate proceedings at a different court. At the same time, bifurcated systems allow for specialization of infringement and invalidity courts. In particular the question of validity requires in-depth technical expertise, which courts that focus on invalidity in a bifurcated system are rather able to provide. This leads presumably to a lower incidence of errors, in particular Type I errors, i.e., fewer invalid patents are erroneously maintained in force.

Our model shows that the separation between validity and infringement reduces the likelihood that an alleged infringer challenges a patent's validity. We confirm that this holds in practice by comparing the likelihood of validity challenges between infringement cases in Germany and the U.K. (a non-bifurcated system where infringement and validity challenges are decided in the same proceedings).[3] The results show that alleged infringers in the U.K. are significantly more likely to challenge a patent's validity than alleged infringers in Germany. We also find empirical evidence that in Germany, in particular smaller firms are less likely to file an invalidity action when they are sued for infringement. We find no evidence that this is also the case in the U.K. These findings suggest that more resource-constrained firms are less likely to challenge a patent's validity in a bifurcated litigation system. The broader implications of this effect are twofold: on the one hand the share of cases where an infringed patent is invalidated is downward biased under bifurcation; on the other hand the strong presumption of validity that is built into the bifurcated litigation system becomes self-reinforcing.

Our model also allows us to compare settlement behavior under the bifurcated and non-bifurcated systems. The model shows that the effect of bifurcation on the extent of adverse selection and its effect on the joint surplus from settlement (the part of the joint surplus from settlement captured by the patent holder) are the two key drivers of the impact of bifurcation on the settlement rate (settlement amount). Depending on the signs and magnitudes of these two effects, bifurcation can either lead to a higher or lower settlement rate (settlement amount). A comparison of settlement behavior between German and U.K. cases reveals that significantly fewer cases settle in the U.K. We also find some evidence that smaller, more resource-constrained firms in Germany are less likely to settle.

Our research contributes to the existing literature on the design and functioning of patent litigation systems by offering for the first time quantitative evidence on the implications of the separation of infringement and validity. This is not only of direct relevance to Germany, where by far the largest number of patent cases in Europe are litigated (Cremers et al., 2016), but also played an important role in the current heated discussion about the design of the Unified Patent Court (UPC) in Europe. For example, a group of large firms across industries, including Adidas, Apple, Deutsche Post DHL, Google, and Samsung,[4] issued a joint statement in 2014 voicing concerns that "[...] the potential exists for a court to order an injunction prohibiting the importation and sale of goods even though the patent may ultimately be found invalid. This result unduly reduces competition, can increase the cost of products in the market and reduce product choices, all negatively impacting consumers."

Apart from its relevance for Germany and the European UPC, our research provides important insights also for countries that rely on similar bifurcated litigation systems, including some of the world's top patenting countries, such as China,

[1] Mann and Underweiser (2012), for example, show that since 2003 the U.S. Federal Circuit has held nearly 60% of patents invalid.

[2] Germany and China have bifurcated systems in which separate courts decide independently on patent infringement and validity. In the U.S., courts decide on both infringement and invalidity simultaneously. However, the Inter Partes Review (IPR) which was introduced by the America Invents Act (AIA) in September 2012 as a way of challenging validity administratively at the U.S. Patent and Trademark Office post-grant has *de facto* introduced bifurcation into the U.S. system (Chien and Helmers, 2015). In 2013, roughly a third of litigated patents in the U.S. were challenged through an IPR.

[3] The U.K. comprises separate legal systems: England & Wales, Scotland and Northern Ireland. Our data focus on England & Wales where the overwhelming majority of cases occur.

[4] The complete list is: Adidas, AFDEL, Apple, ARM, BlackBerry, Broadcom, Bull, Cisco Systems, Dell, Deutsche Post DHL, ESIA, Google, HP, Huawei, Microsoft, Samsung, SFIB, Telecom Italia, and Vodafone.

Japan, and Korea. It also informs jurisdictions that allow for some intermediate degree of separation between infringement and validity. In the U.S., for example, validity challenges in form of an Inter Partes Review (IPR) are decided faster than infringement cases at district courts.[5] Hence, bifurcation in the U.S. means that validity is decided first. Our analysis suggests that this avoids the problem of the injunction gap associated with the German type of bifurcation. Further research could investigate whether the separation of invalidity and infringement decisions introduced by the IPR may even be beneficial.

Taking a broader perspective, our evidence underscores the probabilistic nature of patents. We show that patents that a court presumes valid when deciding on infringement often turn out to be invalid upon closer scrutiny. Patents involved in court disputes are only the tip of the patent iceberg and clearly a non-random selection. Regardless, our evidence supports the general view that legal rights in form of patents are inherently associated with enormous uncertainty. We also show that bifurcation compounds the undersupply of validity challenges in court that has been shown to exist in non-bifurcated systems (Farrell and Merges, 2004). This means that the strong presumption of validity of a probabilistic right, which is built into the bifurcated litigation system, distorts incentives to the patent holder's advantage. Our evidence also suggests that this affects in particular smaller companies as they are less likely to defend themselves against potential patent infringement by challenging the patent's validity. A resulting increased likelihood of facing an injunction for patent infringement may well impact the behavior of smaller companies, it might in particular affect their innovative activity.

Our findings also add to the existing literature on the settlement of patent disputes. Galasso and Schankerman (2010), for example, suggest that the establishment of the Court of Appeals of the Federal Circuit (CAFC) – which was perceived as patentee-friendly – led to more settlements early on in a patent dispute because of reduced uncertainty over the outcome of a case. Our finding that parties are more likely to settle in a bifurcated litigation system due to the lower rate of Type I errors is consistent with the evidence provided by Galasso and Schankerman (2010). Our analysis, therefore, offers empirical evidence directly relevant for the long-standing, largely theoretical debate on the design of patent (enforcement) systems and its effect on companies (Aoki and Hu, 1999; Ayres and Klemperer, 1999; Crampes and Langinier, 2002; Boyce and Hollis, 2007; Eckert and Langinier, 2013).

Our analysis is also related to the law and economics literature on the design of litigation systems more generally. Specifically, there is a theoretical literature on sequential vs. unitary trials (Landes, 1993, 1998; Chen et al., 1997). This literature distinguishes more generally between unitary and sequential trials, where in a sequential trial the legal dispute is broken up into multiple dispositive issues – for example the separation between liability and damages in tort cases in the U.S. The court's decision at each stage of the sequential trial influences the subsequent stage, either directly by shutting the door to proceeding with the next stage or by revealing information about the expected outcome of the next stage.[6] Our setting differs substantially because the trial on the second issue (invalidity) is initiated before the trial on the first issue (infringement) has been decided. Also, the separate trials take place at different courts which increases the additional costs involved in the second (invalidity) trial. Moreover, the second action (invalidity) is taken by the defendant, not the plaintiff in the infringement suit. As such our analysis also contributes to the literature on unitary vs. sequential trials by extending the framework to a setting where a trial is broken into overlapping dispositive issues. Moreover, the analysis of sequential vs. unitary trials so far has been characterized by a complete lack of empirical evidence. As such our empirical analysis offers for the first time empirical evidence on the implications of sequential trials.

Finally, our analysis is also related to the law and economics literature on judicial errors (Png, 1986; Lando, 2006; Rizzolli and Stanca, 2012). Our setting offers a novel perspective on the issue. We show that there is a trade-off in the bifurcated system between a lower probability of a Type I error in the invalidity decision on the one hand, and on the other a higher likelihood of a Type I error in the infringement decision due to the lower likelihood of challenging validity. In other words, conditional on challenging validity, the bifurcated system generates fewer false positives (i.e. more likely to invalidate an invalid patent), but the large cost of challenging validity means that alleged infringers might be found to infringe a patent that would have been invalidated, had its validity been challenged (false positive in the infringement decision).

The remainder of this paper is organized as follows: the next section provides a short description of the German and U.K. patent litigation systems with particular focus on the interplay between infringement and invalidity proceedings. Section 3 discusses our theoretical model. Section 4 describes the data used in our analysis. Section 5 presents our empirical findings and Section 6 offers some concluding thoughts and suggestions for further research. An extensive online appendix provides additional information and analysis.

2. Bifurcated vs. non-bifurcated patent litigation systems

This section explains the design of the German bifurcated patent litigation system as well as the U.K. non-bifurcated system with the discussion focusing on the separation of infringement and invalidity claims.

[5] In any case, infringement cases are usually stayed pending an IPR.

[6] Following Landes (1993), in this literature German bifurcation could be classified as some type of "reverse bifurcation" as validity, which can prevent the infringement suit from proceeding is decided after infringement.

2.1. Germany's bifurcated patent litigation system

2.1.1. Court system

Regional courts (*Landgerichte* – LGs) have jurisdiction over patent infringement.[7] There are 12 regional courts that serve as first instance courts in infringement proceedings.[8] A panel of three legally trained judges decide on infringement. Decisions by the regional courts can be appealed before a higher regional court (*Oberlandesgericht* – OLG). In exceptional cases, a further appeal can be brought before the Patent Division of the German Federal Court of Justice (*Bundesgerichtshof* – BGH) in third instance.

A patent's validity is challenged either through opposition filed at the patent office which granted the patent right (European Patent Office – EPO – for *EP* patents or *Deutsches Patent- und Markenamt* – DPMA – for *DE* patents) or through an invalidity action filed at the German Federal Patent Court (*Bundespatentgericht* – BPatG).[9] As a specialized court, the BPatG deploys judges with both legal and technical training.[10] Appeals to the decisions by the BPatG are directly brought before the Patent Division of the BGH that reviews infringement proceedings. The structure of the German court system is summarized in Fig. A-1 in the online appendix, and online Appendix A provides more details on infringement and invalidity proceedings.

2.1.2. Interaction of infringement and invalidity proceedings

If a patent is invalidated, any pending infringement proceedings based on the patent will be dismissed. This still allows for situations where decisions on infringement can be (preliminarily) enforced based on an invalid patent if infringement is decided before invalidity is. The occurrence of such divergent decisions crucially depends on (a) the timing and (b) duration of infringement and invalidity proceedings:

(a) Mostly filed as a defensive reaction to an infringement action, validity challenges are usually filed after the corresponding infringement proceedings.[11] Fig. A-3 in the online appendix shows the time lag between the filing of infringement and invalidity actions in our data. We find that more than 55% of parallel invalidity proceedings are initiated at least four months after the infringement proceeding.
(b) Invalidity proceedings take significantly longer than infringement proceedings in first instance (see Fig. A-4 in the online appendix), thus increasing the temporal spread between the decisions. Opposition proceedings also take significantly longer than infringement proceedings. The litigants may request acceleration of the proceeding, still, an opposition takes on average 20–30 months.[12]

In combination, (a) and (b) imply in practice that decisions on invalidity follow infringement decisions with a considerable lag.

The alleged infringer may request to stay the infringement proceeding until a decision on validity is available (see Fig. 1). In practice, infringement courts rely by case law on a strong presumption of validity. That is, infringement proceedings are only stayed if there is an overwhelmingly large probability that the patent will not be upheld in its current form. So, even though the judges at the infringement court do not consider the validity of the patent in their judgment on infringement, they have to form an opinion on the likelihood of invalidity to decide on a stay (Fock and Bartenbach, 2010). This poses a considerable challenge as infringement court judges are rarely technically trained and limited resources restrict a thorough investigation of the patent's validity. Usually, the corresponding validity challenges are not yet at a stage where they could provide guidance on the likelihood of invalidity. Infringement court judges are therefore forced to stay at their own discretion.

If decisions on infringement are made faster than decisions on validity, a court may establish infringement although the patent is eventually invalidated. In fact, in Germany, if infringement is found in first instance, any injunction resulting from this decision is enforceable regardless of an appeal or any pending validity challenge. This means the greater the temporal spread between infringement and validity decisions, the longer a patent may be wrongfully enforced. Even if the patent is invalidated in first instance, the patent holder can continue to enforce the patent as long as the decision is not binding. This injunction gap may, therefore, extend beyond the first instance invalidity decision. This creates strong incentives to appeal the infringement decision while awaiting the outcome of the validity challenge. The result is considerable legal uncertainty over the outcome of the infringement dispute, potential delays in enforcement, increased litigation costs, and the possibility of an injunction gap.

[7] Infringement claims must be based on a patent granted by the DPMA (*DE*) or the EPO with effect for Germany (*EP*).
[8] These are the regional courts in Berlin, Braunschweig, Düsseldorf, Erfurt, Frankfurt, Hamburg, Leipzig, Magdeburg, Mannheim, Munich, Nuremberg-Furth, and Saarbrücken. Each regional court has at least one chamber primarily designated to patent cases.
[9] The responsibilities of the BPatG are twofold. It serves as the appeals court for decisions of the DPMA concerning *DE* patent applications, and it hears invalidity actions for *DE* and *EP* (with effect for Germany) patents.
[10] The panel consists of five judges: three technically trained judges as well as two legally trained judges.
[11] This is often due to the time required to prepare the case, in particular the search for prior art that can be used to challenge the patent's validity (Kühnen, 2013).
[12] Harhoff et al. (2007) reports a median length of opposition proceedings at the EPO of about four years (including appeal).

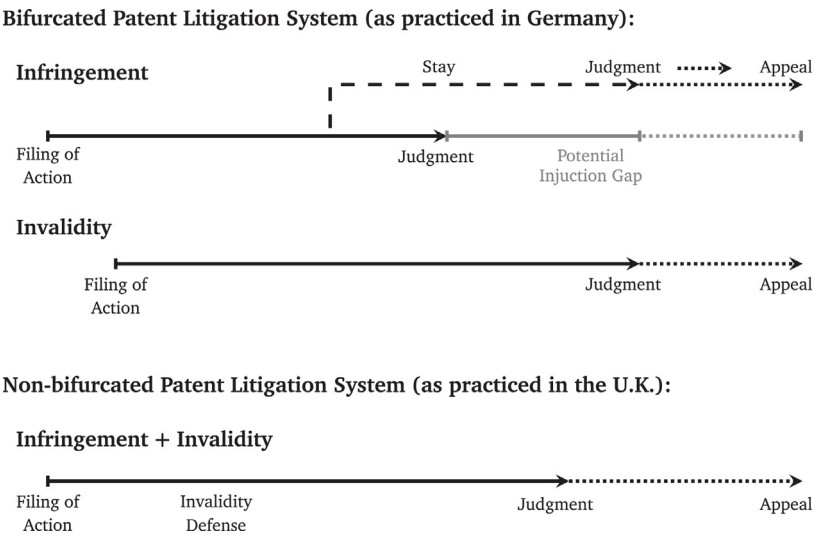

Fig. 1. Timing of infringement and invalidity proceedings in bifurcated and non-bifurcated systems.

2.2. U.K.'s non-bifurcated patent litigation system

In the U.K. patent disputes are heard exclusively by two courts,[13] the Patents County Court (PCC), which was renamed to Intellectual Property Enterprise Court (IPEC) at the end of 2013,[14] and the Patents Court, a specialist court part of the High Court of England and Wales (see Fig. A-2 in the online appendix).[15] Both courts are located in London. The IPEC generally hears cases of lower value and complexity, with total recoverable costs and damages capped at £50,000 and £500,000 respectively. In both courts, cases are decided by a single, technically trained judge. Appeals are heard by the Court of Appeal (CA) and in exceptional cases by the Supreme Court (formerly the House of Lords).

The U.K. patent litigation system is non-bifurcated, which means that infringement and invalidity claims are decided simultaneously (see Fig. 1). As a result, if a patent is invalidated by the court, it cannot be found to be infringed. Therefore, the invalid but infringed scenario cannot arise in the non-bifurcated system. That said, invalidity challenges still have to be raised as counterclaims and pursued by the defendants.[16] The structure of the U.K. court system is summarized in Fig. A-2 in the online appendix, and online Appendix B offers more details on the U.K. litigation system.

3. Model

This section presents a model that illustrates the key trade-off between bifurcated and non-bifurcated systems and explores its implications on parties' incentives to sue for patent infringement, challenge validity, and settle the case.

3.1. Litigation in the non-bifurcated system

We consider a patent holder (plaintiff) P and an alleged infringer (defendant) D. The patent holder can decide whether to sue the alleged infringer. If he does so, the alleged infringer can file a counterclaim to invalidate the patent. In this section we consider a non-bifurcated litigation system: whenever the patent's validity is challenged, the issues of infringement and validity are decided *simultaneously* by the *same* court. Hence, we assume that the alleged infringer does not need to incur any additional litigation costs to challenge the patent's validity.

Denote C_P and C_D the litigation costs of the patent holder and the alleged infringer, respectively. Furthermore, denote θ the probability that a court finds the defendant to infringe the patent and α^{nb} the probability that the patent's validity is upheld by the court if challenged. If the court finds that the patent is invalid, the alleged infringer gets a payoff I_D, which

[13] Infringement claims must be based on a patent granted by the U.K. Intellectual Property Office (*GB*) or the EPO with effect for the U.K. (*EP*).

[14] The PCC/IPEC underwent a series of comprehensive reforms between 2010 and 2013 which are described in Fox (2014) and Helmers et al. (2015).

[15] Infringement claims must be based on a patent granted by the U.K. Intellectual Property Office or the EPO with effect for the U.K. Note that the U.K. Intellectual Property office does not grant utility models.

[16] Note that validity of EP patents can also be challenged through opposition at the EPO, but there is no opposition procedure for national patents with the U.K. Intellectual Property Office (although there is a procedure via its opinion service).

is allowed to be either positive, negative or zero,[17] while the patent holder incurs a loss L_P (i.e., gets a payoff $-L_P$).[18] If the court finds that the patent is valid and infringed, the patent holder derives a benefit B_P,[19] while the infringer incurs a loss L_D (i.e., gets a payoff $-L_D$).[20] If the court finds that the patent is valid but not infringed, we assume that neither the alleged infringer nor the patent holder are affected by this decision. The probability of infringement $\theta \in \left(\underline{\theta}, \overline{\theta}\right]$ is known to the alleged infringer while the patent holder only knows that it is drawn from a uniform distribution over $\left(\underline{\theta}, \overline{\theta}\right]$.

The timing of the game is as follows:

Stage 1: The patent holder P decides whether to sue the alleged infringer D. If he does not sue for infringement, the game ends. If he does, the game proceeds to the next stage.
Stage 2: The alleged infringer D decides whether to challenge the patent's validity.
Stage 3: The court hands down its judgment regarding infringement and validity if the patent's validity was challenged. in Stage 2. Otherwise, the court hands down its judgment regarding the infringement claim.

Consider first the alleged infringer's incentives to challenge the patent's validity. If the alleged infringer decides to file an invalidity counterclaim in Stage 2, his expected payoff is given by $-\alpha^{nb}\theta L_D + (1-\alpha^{nb})I_D - C_D$, while his expected payoff if he decides not to do so is $-\theta L_D - C_D$. Therefore, the alleged infringer challenges the patent's validity if and only if

$$-\alpha^{nb}\theta L_D + \left(1-\alpha^{nb}\right) I_D - C_D > -\theta L_D - C_D$$

which is the same as

$$I_D > -\theta L_D$$

Since $\theta \in \left(\underline{\theta}, \overline{\theta}\right]$, the latter holds if and only if

$$\theta > \tilde{\theta}^{nb} \equiv \begin{cases} \underline{\theta} & \text{if} \quad \underline{\theta} > \dfrac{-I_D}{L_D} \\ \dfrac{-I_D}{L_D} & \text{if} \quad \dfrac{-I_D}{L_D} \in \left[\underline{\theta}, \overline{\theta}\right) \\ \overline{\theta} & \text{if} \quad \overline{\theta} \leq \dfrac{-I_D}{L_D} \end{cases}$$

When $\tilde{\theta}^{nb} = \underline{\theta}$, the alleged infringer always challenges the patent's validity. If $-I_D/L_D \in \left[\underline{\theta}, \overline{\theta}\right)$, he does so only when the probability of infringement is large enough. Finally, if $\tilde{\theta}^{nb} = \overline{\theta}$, he never challenges the patent's validity.

Let us now consider the patent holder's incentives to sue for infringement. The patent holder's expected payoff from suing the alleged infringer is

$$\frac{1}{\overline{\theta}-\underline{\theta}}\left\{\int_{\underline{\theta}}^{\tilde{\theta}^{nb}} \left(\theta B_P - C_P\right) d\theta + \int_{\tilde{\theta}^{nb}}^{\overline{\theta}} \left[\theta\alpha^{nb}B_P - \left(1-\alpha^{nb}\right)L_P - C_P\right] d\theta\right\} = \frac{1}{\overline{\theta}-\underline{\theta}}\left\{\left(1-\alpha^{nb}\right)\left[\frac{B_P}{2}\left(\tilde{\theta}^{nb}\right)^2 + L_P\tilde{\theta}^{nb} - L_P\overline{\theta}\right]\right.$$
$$\left. + \frac{\alpha^{nb}B_P}{2}\overline{\theta}^2 - \frac{B_P}{2}\underline{\theta}^2\right\} - C_P$$

because the alleged infringer challenges the patent's validity if and only if $\theta > \tilde{\theta}^{nb}$. Therefore, the patent holder will sue the alleged infringer if and only if

$$C_P \leq \frac{1}{\overline{\theta}-\underline{\theta}}\left\{\left(1-\alpha^{nb}\right)\left[\frac{B_P}{2}\left(\tilde{\theta}^{nb}\right)^2 + L_P\tilde{\theta}^{nb} - L_P\overline{\theta}\right] + \frac{\alpha^{nb}B_P}{2}\overline{\theta}^2 - \frac{B_P}{2}\underline{\theta}^2\right\} \equiv \tilde{C}_P^{nb} \tag{1}$$

[17] One reason why I_D can be negative is that invalidating a patent is similar to removing an entry barrier, which may hurt both the patent holder and the alleged infringer. The payoff I_D can be positive if the patent's invalidation allows the alleged infringer to save some costs he was incurring to build around the patent and reduce the probability of infringing it. Another reason why I_D can be positive is that the alleged infringer may be using a technology that he was unable to license to third parties when the patent was still presumed valid (because potential licensees fear infringing that patent) but that he can license if the patent is invalidated. Finally, if the patent holder was "hiding" his patent and shows up only after the alleged infringer has made an action that could infringe the patent, it is reasonable to assume that $I_D = 0$.

[18] The patent holder may incur this loss because current licensees will stop paying their license fees.

[19] The benefit B_P may capture for instance the damages paid by the infringer and/or additional market profits resulting from an injunction.

[20] The loss L_D may capture for instance the damages paid to the patent holder and/or any loss in market profits due to an injunction.

3.2. Litigation in the bifurcated system

In the bifurcated litigation system, validity and infringement of a patent are decided separately and independently. We assume that two different courts deal with infringement and validity and that the court dealing with infringement hands down its judgment first. To account for the main features of the bifurcated system, we modify the benchmark setting above in a number of ways. First, we consider an alternative timing:

Stage 1: The patent holder P decides whether to sue the alleged infringer D. If he does not sue for infringement, the game ends. If he does, the game proceeds to the next stage.
Stage 2: The alleged infringer D decides whether to challenge the patent's validity.
Stage 3: The court dealing with infringement hands down its judgment.
Stage 4: The court dealing with validity hands down its judgment if the patent's validity was challenged in Stage 2.

Second, we assume that challenging the patent's validity before another court requires additional litigation cost c_D for the alleged infringer. Third, we assume that when the patent is found infringed and eventually invalidated, the alleged infringer gets a payoff $I_D - l_D$ where $l_D \geq 0$ (instead of I_D under the non-bifurcated system), and the patent holder receives a payoff $b_P - L_P$ where $b_P \geq 0$ (instead of $-L_P$ under the non-bifurcated system). This captures the fact that during the period between the decisions by the two courts (the injunction gap), the patent holder may be able to enforce his patent, for instance through an injunction.[21]

Finally, assume that the probability that the patent's validity is upheld under the bifurcated system, which we denote α^b, is smaller than the corresponding probability under the non-bifurcated system: $\alpha^b \leq \alpha^{nb}$. This captures the fact that a non-specialized court is more likely to make a Type I error when assessing the validity of a patent. It is indeed reasonable to assume that a specialized court is rather able to assess the relevance of prior art to invalidate the patent than a non-specialized court.[22] Note that, in our model, the non-bifurcated system can be regarded as a special case of the bifurcated system in which $c_D = 0$, $l_D = 0$, $b_P = 0$, and $\alpha^b = \alpha^{nb}$.

In this setting, the alleged infringer will challenge the patent's validity if and only if his expected payoff from doing so

$$-\theta\alpha^b L_D + \theta\left(1-\alpha^b\right)\left(I_D - l_D\right) + \left(1-\theta\right)\left(1-\alpha^b\right) I_D - C_D - c_D$$

is greater than his expected payoff from facing the infringement suit without challenging the patent's validity, i.e., $-\theta L_D - C_D$. Hence, the patent's validity will be challenged if and only if

$$\theta > \frac{-I_D}{L_D - l_D} + \frac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)}$$

Since $\theta \in \left(\underline{\theta}, \overline{\theta}\right]$, the latter holds if and only if

$$\theta > \tilde{\theta}^b \equiv \begin{cases} \underline{\theta} & \text{if} \quad \underline{\theta} > \dfrac{-I_D}{L_D - l_D} + \dfrac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)} \\ \dfrac{-I_D}{L_D - l_D} + \dfrac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)} & \text{if} \quad \dfrac{-I_D}{L_D - l_D} + \dfrac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)} \in \left[\underline{\theta}, \overline{\theta}\right) \\ \overline{\theta} & \text{if} \quad \overline{\theta} \leq \dfrac{-I_D}{L_D - l_D} + \dfrac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)} \end{cases}$$

Let us now examine the patent holder's decision to sue for infringement. If validity is challenged then the patent holder's expected payoff is

$$\theta\alpha^b B_p + \theta\left(1-\alpha^b\right)\left(b_P - L_P\right) - \left(1-\theta\right)\left(1-\alpha^b\right) L_P - C_P$$

which can be rewritten as

$$\theta\left(\alpha^b B_p + \left(1-\alpha^b\right) b_P\right) - \left(1-\alpha^b\right) L_P - C_P$$

[21] In Germany, the alleged infringer may seek compensation after the patent is invalidated but is typically unable to get full compensation (see also Section 2.1.2).

[22] A key argument for specialization is that sufficient judicial expertise with the law as well as with technology is crucial for accurate decision-making in patent litigation (cf. Moore, 2001; Pegram, 2000; Kesan and Ball, 2011). In particular, in order to accurately determine a patent's validity, judges require a sound understanding of the relevant, potentially invalidating, prior art. This usually requires in-depth knowledge of the corresponding technology field. Inline with this argument, we assume that judges at specialized courts are more likely to have that knowledge thanks to their technical background and training. They are also in a better position to accumulate technological expertise due to their focus on patent validity.

Thus, the patent holder's expected payoff from suing the alleged infringer is

$$\frac{1}{\overline{\theta}-\underline{\theta}}\left\{\int_{\underline{\theta}}^{\tilde{\theta}^b}\theta B_P d\theta+\int_{\tilde{\theta}^b}^{\overline{\theta}}\left[\theta\left(\alpha^b B_P+\left(1-\alpha^b\right)b_P\right)-\left(1-\alpha^b\right)L_P\right]d\theta\right\}-C_P=\frac{1}{\overline{\theta}-\underline{\theta}}\left\{\left(1-\alpha^b\right)\left[\frac{(B_P-b_P)}{2}\left(\tilde{\theta}^b\right)^2\right.\right.$$
$$\left.\left.+L_P\tilde{\theta}^b-L_P\overline{\theta}\right]+\frac{\alpha^b B_P+\left(1-\alpha^b\right)b_P}{2}\overline{\theta}^2-\frac{B_P}{2}\underline{\theta}^2\right\}-C_P$$

because the alleged infringer challenges the patent's validity if and only if $\theta>\tilde{\theta}^b$. Therefore, the patent holder will sue the alleged infringer if and only if

$$C_P\leq\frac{1}{\overline{\theta}-\underline{\theta}}\left\{\left(1-\alpha^b\right)\left[\frac{(B_P-b_P)}{2}\left(\tilde{\theta}^b\right)^2+L_P\tilde{\theta}^b-L_P\overline{\theta}\right]+\frac{\alpha^b B_P+\left(1-\alpha^b\right)b_P}{2}\overline{\theta}^2-\frac{B_P}{2}\underline{\theta}^2\right\}\equiv\tilde{C}_P^b \tag{2}$$

3.3. Comparison of the two systems

Let us first compare the alleged infringer's incentives to challenge validity under the two systems. This boils down to comparing the thresholds $\tilde{\theta}^{nb}$ and $\tilde{\theta}^b$.

We need to distinguish two cases:

1 If $I_D>0$ then $\tilde{\theta}^{nb}=\underline{\theta}\leq\tilde{\theta}^b$.
2 If $I_D\leq 0$ then

$$\frac{-I_D}{L_D}\leq\frac{-I_D}{L_D-l_D}+\frac{c_D}{\left(1-\alpha^b\right)(L_D-l_D)}$$

which yields

$$\tilde{\theta}^{nb}=\min\left(\max\left(\frac{-I_D}{L_D},\underline{\theta}\right),\overline{\theta}\right)\leq\min\left(\max\left(\frac{-I_D}{L_D-l_D}+\frac{c_D}{\left(1-\alpha^b\right)(L_D-l_D)},\underline{\theta}\right),\overline{\theta}\right)=\tilde{\theta}^b$$

Thus, in both cases, it holds that $\tilde{\theta}^{nb}\leq\tilde{\theta}^b$, which yields the following result:

Proposition 1. *Bifurcation has a negative effect on the alleged infringer's incentives to challenge the patent's validity.*

Let us now compare the patent holder's incentives to sue for infringement under both systems. To do that, we need to compare the thresholds $\tilde{C}_P^{nb}$ and $\tilde{C}_P^b$.

From (2) it follows that $\tilde{C}_P^b$ increases with α^b and b_P and decreases with c_D (because $\tilde{\theta}^b$ increases with c_D). This, combined with the fact that $\tilde{C}_P^{nb}$ is equal to $\tilde{C}_P^b$ in the special case $\alpha^b=\alpha^{nb}$, $b_P=0$ and $c_D=0$, shows that a switch from the non-bifurcated system to the bifurcated system affects the patent holder's incentives to sue for infringement through two opposite forces:

1 The existence of an injunction gap (and more precisely the benefit b_P the patent holder derives from it) and the deterrence effect of the additional cost c_D to challenge the patent's validity increases the patent holder's incentives to sue for infringement.
2 The decrease in Type I errors (and the corresponding decrease in the probability that the patent's validity is upheld by the court) decreases the patent holder's incentives to sue for infringement.

These two opposite forces capture the trade-off induced by bifurcation from the patent holder's perspective. Whether the patent holder will have higher or lower incentives to sue for infringement under the bifurcated system (i.e. whether $\tilde{C}_P^b$ is higher or lower than $\tilde{C}_P^{nb}$) depends on the relative magnitude of these two forces: the higher b_P and c_D (the lower α^b), the higher (lower) the likelihood that bifurcation will result in more infringement suits.

Thus, we get the following result:

Proposition 2. *Bifurcation has an ambiguous effect on the patent holder's incentives to sue for infringement.*

3.4. Testable predictions

Proposition 2 produces ambiguous predictions regarding the decision to sue for patent infringement. Unfortunately, this prediction is not empirically testable because it would require data on the population of patent disputes. However, only disputes that are litigated in court are visible, hence we are unable to compute the patent holder's propensity to sue for infringement.

In contrast, our model (Proposition 1) generates a clear-cut result regarding the effect of bifurcation on validity challenges which leads to a prediction that can be tested using the available data:

Prediction 1: Alleged infringers challenge patent validity less often under a bifurcated system than under a non-bifurcated system.

In our model, the alleged infringer's incentives to challenge validity depends on his litigation costs under the bifurcated system (through the additional cost c_D he has to incur to file an invalidity counterclaim in a different court), while this is not true under the non-bifurcated system. This implies that the alleged infringer's characteristics that affect his litigation costs (in particular c_D) should affect his incentives to challenge validity under the bifurcated system but not under the non-bifurcated system. We focus here on the effect of the defendant's size s_D on these incentives.

More specifically, we make the following assumption: other things equal, smaller defendants incur higher litigation costs, i.e. $\partial c_D/\partial s_D < 0$. Smaller firms are commonly seen as more resource-constrained due to higher capital costs (Carpenter and Petersen, 2002; Hall, 2002). Therefore, it is not surprising that several studies have found that patent litigation places a heavier burden on smaller companies (Lerner, 1995; Lanjouw and Lerner, 2001; Agarwal et al., 2009; Bessen and Meurer, 2013). Greenhalgh et al. (2010) offer direct qualitative survey-based evidence that indicates that the burden imposed by patent litigation costs is inversely proportional to firm size. In particular, time and management resources that have to be dedicated to litigation weigh heavier on small companies. Small firms are also less likely to afford in-house legal counsel, which further increases their costs of litigation (Lanjouw and Schankerman, 2004).

Under the above assumption, the threshold $\tilde{\theta}^b$ above which an alleged infringer decides to challenge validity increases with his size s_D. Therefore, our model generates the following testable prediction:

Prediction 2: Other things equal, smaller defendants are less likely to challenge validity under the bifurcated system, while the size of alleged infringers does not affect their incentives to challenge validity under the non-bifurcated system.

3.5. Extension: settlement

In an extension of the model, we allow the patent holder and the alleged infringer to reach a settlement before the court judgment. More specifically, we allow the patent holder to make a take-it-or-leave-it settlement offer to the alleged infringer before the latter decides whether to file an invalidity counterclaim. Given that the alleged infringer has private information about the infringement probability, the settlement subgame is a screening game in which the patent holder makes a settlement offer which is accepted (turned down) by defendants that have a probability of infringement above (below) a critical threshold. We characterize the equilibrium settlement amount and critical threshold under both systems and compare them.

We consider the following extension of the game studied above:

Stage 1: *P* decides whether to file an infringement claim. If he does not, the game ends; otherwise, it proceeds to the next stage.
Stage 2: *P* makes a take-it-or-leave-it settlement offer to *D*.[23]
Stage 3: *D* decides whether to accept the offer. If it is accepted, the game ends; otherwise it proceeds to the next stage.
Stage 4: *P* decides whether to drop the infringement case. If he does, the game ends; otherwise, the patent holder and the alleged infringer incur litigation costs C_P and C_D, respectively, and the game proceeds to the next stage.
Stage 5: *D* decides whether to challenge the patent's validity (before the same court under the non-bifurcated system and before a different court under the bifurcated system).
Stage 6: Court decisions regarding infringement, and validity if challenged, are handed down.[24]

[23] We focus on settlements that occur after a claim is filed because these are the only ones that we can observe in the data.

[24] For the sake of exposition, we present a unified model in which court decisions are handed down in the same stage under both systems. Since the courts are not strategic players in our setting, modeling their actions as simultaneous moves under the bifurcated system (rather than sequential moves) leads to the same outcomes as long all the payoff functions remain the same.

As is standard in the theoretical literature on settlement,[25] we assume that the patent holder's litigation threat is always credible. This holds true under both the bifurcated and non-bifurcated systems if the following (sufficient) conditions hold

$$-C_P + \underline{\theta}\alpha^{nb}B_P - \left(1-\alpha^{nb}\right)L_P \geq 0$$

and

$$-C_P + \underline{\theta}\left[\alpha^{b}B_P + \left(1-\alpha^{b}\right)b_P\right] - \left(1-\alpha^{b}\right)L_P \geq 0$$

that is, if

$$\underline{\theta} \geq \min\left(\frac{C_P + \left(1-\alpha^{nb}\right)L_P}{\alpha^{nb}B_P}, \frac{C_P + \left(1-\alpha^{b}\right)L_P}{\alpha^{b}B_P + \left(1-\alpha^{b}\right)b_P}\right)$$

This assumption implies that if settlement fails, the patent holder will never drop the case in Stage 4.

We make another two simplifying assumptions. First, we assume that the alleged infringer's payoff if the patent is invalidated under the non-bifurcated system is $I_D = 0$.[26] This simplifies the analysis by reducing the number of possible scenarios. In particular, the alleged infringer will always file an invalidity counterclaim under the non-bifurcated system (in Stage 5) if he does not accept the settlement offer (in Stage 3). Second, we assume that the patent holder's benefit from the patent being found infringed and valid (the injunction gap) is equal to the alleged infringer's loss: $B_P = L_D$ (respectively, $b_P = l_D$).[27] This assumption substantially simplifies the mathematical expressions and, therefore, the comparison between the outcomes under the bifurcated and non-bifurcated systems.

3.5.1. Settlement in the non-bifurcated system

Under the non-bifurcated system, the alleged infringer always challenges the patent's validity in Stage 5 if he turns down the settlement offer in Stage 3. Let us now consider his decision in Stage 3. He accepts to pay an amount S to settle the infringement case if and only if this amount is less than his expected cost from not accepting the settlement offer, i.e.,

$$S < \alpha^{nb}\theta L_D + C_D$$

which is the same as

$$\theta > \hat{\theta}^{nb}(S) \equiv \frac{S - C_D}{\alpha^{nb}L_D}$$

Intuitively, the higher the settlement amount, the lower the probability that the settlement offer is accepted by the alleged infringer.

Let us now consider the patent holder's decision in Stage 2. The patent holder knows that a settlement offer involving an amount S will always be accepted (i.e., will be accepted by all types of defendants) if and only if

$$S \leq \underline{S}^{nb} \equiv \alpha^{nb}\underline{\theta}L_D + C_D$$

and that a settlement offer will always be turned down if and only if

$$S > \overline{S}^{nb} \equiv \alpha^{nb}\overline{\theta}L_D + C_D$$

The patent holder also knows that an offer $S \in \left(\underline{S}^{nb}, \overline{S}^{nb}\right]$ will be accepted by the alleged infringer with probability $(\overline{\theta} - \hat{\theta}^{nb}(S))/(\overline{\theta} - \underline{\theta})$ and turned down with probability $(\hat{\theta}^{nb}(S) - \underline{\theta})/(\overline{\theta} - \underline{\theta})$. In the latter scenario, the patent holder's probability of winning (i.e., the probability that the patent is found valid and infringed) is

$$\alpha^{nb}\frac{\int_{\underline{\theta}}^{\hat{\theta}^{nb}(S)}\theta d\theta}{\hat{\theta}^{nb}(S) - \underline{\theta}} = \frac{\alpha^{nb}}{2}\left(\hat{\theta}^{nb}(S) + \underline{\theta}\right)$$

The following lemma provides the equilibrium settlement amount $\tilde{S}^{nb}$ and the corresponding probability threshold $\tilde{\theta}^{nb} = \hat{\theta}^{nb}\left(\tilde{S}^{nb}\right)$ above which the settlement offer is accepted.

[25] See e.g. the survey by Spier (2007).

[26] I_D also enters the alleged infringer's payoffs under the bifurcated system.

[27] The assumption $B_P = L_D$ would hold for instance if the plaintiff's (defendant's) only benefit (loss) from the patent being found valid and infringed is the damages paid by the defendant to the plaintiff. The assumption $b_P = l_D$ would hold for instance if the defendant's loss from the injunction gap takes the form of license fees paid to the patent holder.

Lemma 1. *The equilibrium settlement amount is given by*

$$\tilde{S}^{nb} = \begin{cases} \alpha^{nb} L_D \overline{\theta} - C_P - \left(1-\alpha^{nb}\right) L_P & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P + \left(1-\alpha^{nb}\right) L_P}{\alpha^{nb} L_D} \\ \alpha^{nb} \underline{\theta} L_D + C_D & \text{otherwise} \end{cases} \tag{3}$$

and the equilibrium offer is accepted by an alleged infringer if and only if

$$\theta > \tilde{\theta}^{nb} = \begin{cases} \overline{\theta} - \dfrac{C_P + C_D + \left(1-\alpha^{nb}\right) L_P}{\alpha^{nb} L_D} & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P + \left(1-\alpha^{nb}\right) L_P}{\alpha^{nb} L_D} \\ \underline{\theta} & \text{otherwise} \end{cases} \tag{4}$$

Proof. See online Appendix C. □

We find that the equilibrium settlement amount $\tilde{S}^{nb}$ is (weakly) increasing in L_D, C_D and α^{nb} and (weakly) decreasing in C_P and L_P, which is consistent with the intuition that the settlement amount should increase if the patent holder's (respectively, alleged infringer's) payoff in case settlement fails increases (respectively, decreases).

Note also that $\tilde{S}^{nb}$ is always such that a positive fraction of alleged infringers accept the settlement offer. In other words, in our setup, the plaintiff never finds it optimal to make a settlement offer that is turned down by all defendant types (which would the same as not making a settlement offer at all).[28]

3.5.2. Settlement in the bifurcated system

Under the bifurcated system, it is no longer the case that the alleged infringer always challenges the patent's validity if he turns down the settlement offer. Under the assumption $I_D = 0$, he will do so if and only if

$$c_D < \theta \left(1-\alpha^b\right)\left(L_D - l_D\right)$$

which can be rewritten as

$$\theta > \breve{\theta}(c_D) \equiv \frac{c_D}{\left(1-\alpha^b\right)\left(L_D - l_D\right)}$$

Therefore, the alleged infringer accepts to pay an amount S to settle the infringement case if and only if

$$S < \min\left(\alpha^b \theta L_D + \left(1-\alpha^b\right)\theta l_D + C_D + c_D, \theta L_D + C_D\right)$$

which can be rewritten as

$$\theta \geq \hat{\theta}^b(S, c_D) \equiv \begin{cases} \dfrac{S - C_D}{L_D} & \text{if} \quad \theta \leq \breve{\theta}(c_D) \\ \dfrac{S - C_D - c_D}{\alpha^b L_D + \left(1-\alpha^b\right) l_D} & \text{if} \quad \theta > \breve{\theta}(c_D) \end{cases}$$

3.5.3. Comparison of the two systems

We investigate here the effect of bifurcation on the (equilibrium) settlement amount and settlement rate, focusing on the two polar scenarios $\breve{\theta}(c_D) < \underline{\theta}$ and $\breve{\theta}(c_D) \geq \overline{\theta}$.

Scenario 1: $\breve{\theta}(c_D) < \underline{\theta}$ (or, equivalently, "low" c_D)

In this case, the additional litigation cost an alleged infringer has to incur to file an invalidity counterclaim never prevents him from challenging the patent's validity (when settlement fails). We can then derive the equilibrium settlement amount

[28] Note however that this need not hold if we relax the assumption $B_P = L_D$. In particular, Remark 1 in online Appendix C shows that the patent holder finds it optimal to make a settlement offer that is turned down with certainty if

$$B_P > \max\left(2L_D, \frac{2}{\alpha^{nb}\left(\underline{\theta}+\overline{\theta}\right)}\left[\alpha^{nb}\underline{\theta}L_D + \left(1-\alpha^{nb}\right)L_P + C_P + C_D\right]\right).$$

$\tilde{S}^b$ and the corresponding probability threshold $\tilde{\theta}^b = \hat{\theta}^b(\tilde{S}^b, c_D)$ from the analysis of the non-bifurcated system by replacing C_D with $C_D + c_D$, $\left(1-\alpha^{nb}\right) L_P$ with $\left(1-\alpha^b\right) L_P$, and $\alpha^{nb} L_D$ with $\alpha^b L_D + \left(1-\alpha^b\right) l_D$:

$$\tilde{S}^b = \begin{cases} \left(\alpha^b L_D + \left(1-\alpha^b\right) l_D\right) \overline{\theta} - C_P - \left(1-\alpha^b\right) L_P & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P + \left(1-\alpha^b\right) L_P}{\alpha^b L_D + \left(1-\alpha^b\right) l_D} \\ \alpha^b \underline{\theta} L_D + C_D & \text{otherwise} \end{cases} \tag{5}$$

and

$$\tilde{\theta}^b = \begin{cases} \overline{\theta} - \dfrac{C_P + C_D + c_D + \left(1-\alpha^b\right) L_P}{\alpha^b L_D + \left(1-\alpha^b\right) l_D} & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P + \left(1-\alpha^b\right) L_P}{\alpha^b L_D + \left(1-\alpha^b\right) l_D} \\ \underline{\theta} & \text{otherwise} \end{cases} \tag{6}$$

We can now derive the effects of bifurcation on settlement from the comparison of the equilibrium outcomes under both systems. For the sake of exposition, we focus on the set of parameters leading to interior solutions under both systems, i.e.,

$$\overline{\theta} - \underline{\theta} \geq \frac{C_D + C_P + c_D + \left(1-\alpha^b\right) L_P}{\min\left(\alpha^{nb} L_D, \alpha^b L_D + \left(1-\alpha^b\right) l_D\right)}$$

Effect of bifurcation on the settlement amount: The equilibrium settlement amount under the non-bifurcated system can be written as

$$\tilde{S}^{nb} = A^{nb}\overline{\theta} - \Delta_P^{nb}$$

where

$$A^{nb} \equiv \alpha^{nb} L_D \quad \text{and} \quad \Delta_P^{nb} \equiv C_P + \left(1-\alpha^{nb}\right) L_P$$

The term A^{nb} measures the extent of adverse selection under the non-bifurcated system: it becomes more costly for the patent holder to separate defendant types when A^{nb} increases. To see why, notice that the informational rent that a patent holder leaves to defendants that have a type θ above the borderline type $\hat{\theta}^{nb}(S)$ is $\left(\alpha^{nb}\theta L_D + C_D\right) - S$, which is increasing in A^{nb}.

In order to interpret Δ_P^{nb}, note first that, under the non-bifurcated system, settlement generates joint surplus

$$\Delta^{nb} \equiv C_P + \left(1-\alpha^{nb}\right) L_P + C_D$$

for the patent holder and the alleged infringer. The term Δ_P^{nb} is the part of this joint surplus captured by the patent holder, gross of the settlement amount.

Similarly, we can write the equilibrium settlement amount under the bifurcated system as

$$\tilde{S}^b = A^b\overline{\theta} - \Delta_P^b$$

where

$$A^b \equiv \alpha^b L_D + \left(1-\alpha^b\right) l_D \quad \text{and} \quad \Delta_P^b \equiv C_P + \left(1-\alpha^b\right) L_P$$

are the counterparts of A^{nb} and Δ_P^{nb} under the bifurcated system. Denote also

$$\Delta^b \equiv C_P + \left(1-\alpha^{nb}\right) L_P + C_D + c_D$$

the counterpart of Δ^{nb} under the bifurcated system (when the alleged infringer files an invalidity couterclaim whenever settlement fails, as in the current scenario).

Thus,

$$\tilde{S}^b - \tilde{S}^{nb} = \left(A^b - A^{nb}\right)\overline{\theta} - \left(\Delta_P^b - \Delta_P^{nb}\right) \tag{7}$$

This shows that the comparison of the equilibrium settlement amounts under the two systems depends on the following two effects:

a. The effect of bifurcation on the extent of adverse selection, which is captured by $A^b - A^{nb}$. An increase (decrease) in the extent of adverse selection has a positive (negative) effect on the settlement amount. The intuition behind this is that

more adverse selection provides the patent holder with larger incentives to limit the informational rent left to the alleged infringer types that accept to settle by increasing the settlement amount that he requests.

b. The effect of bifurcation on the part of the joint surplus from settlement captured by the patent holder (gross of the settlement amount). Note that the sign of this effect is always positive:

$$\Delta_P^b - \Delta_P^{nb} = \left(\alpha^{nb} - \alpha^b\right) L_P \geq 0$$

because the probability that the patent is invalidated when challenged is higher under the bifurcated system. This means that, for a given settlement amount, the patent holder's part of the surplus from settlement under the bifurcated system is greater than its counterpart under the non-bifurcated system. This effect of bifurcation increases the patent holder's incentives to make a less demanding offer in order to increase the probability of reaching a settlement.

Therefore, we need to distinguish between two cases:

1 If $A^b \leq A^{nb}$ then both effects lead to a decrease of the settlement amount and, therefore, the overall effect of bifurcation on the settlement amount is negative.
2 If $A^b > A^{nb}$ then the effect of bifurcation on adverse selection affects positively the settlement amount while the effect of bifurcation on the part of the joint surplus from settlement captured by the patent holder affects negatively the settlement amount. Therefore, the overall effect of bifurcation is ambiguous in this case.

Effect of bifurcation on the settlement rate: Denote $\tilde{r}^b \equiv \frac{\overline{\theta}-\tilde{\theta}^b}{\overline{\theta}-\underline{\theta}}$ the equilibrium settlement rate under the bifurcated system and $\tilde{r}^{nb} \equiv \frac{\overline{\theta}-\tilde{\theta}^{nb}}{\overline{\theta}-\underline{\theta}}$ its counterpart under the non-bifurcated system. From (4) and (6) it follows that

$$\tilde{r}^{nb} = \frac{1}{\overline{\theta}-\underline{\theta}} \frac{\Delta^{nb}}{A^{nb}}$$

and

$$\tilde{r}^{b} = \frac{1}{\overline{\theta}-\underline{\theta}} \frac{\Delta^{b}}{A^{b}}$$

Therefore,

$$\frac{\tilde{r}^b}{\tilde{r}^{nb}} = \frac{\Delta^b/\Delta^{nb}}{A^b/A^{nb}} \tag{8}$$

Thus, the effect of bifurcation on the settlement rate depends on its effect on the joint surplus from settlement (how Δ^b/Δ^{nb} compares to 1) and its effect on the extent of adverse selection (i.e., how A^b/A^{nb} compares to 1).

Note first that the joint surplus generated by a settlement is always greater under the bifurcated system than under the non-bifurcated system:

$$\frac{\Delta^b}{\Delta^{nb}} - 1 = \frac{\Delta^b - \Delta^{nb}}{\Delta^{nb}} = \frac{\left(\alpha^{nb} - \alpha^b\right) L_P + c_D}{\Delta^{nb}} \geq 0$$

The reason for this is that bifurcation induces a higher expected loss from invalidation for the patent holder and higher litigation costs for the alleged infringer. This increase in the joint surplus from settlement increases the parties' incentives to settle, which explains why it has a positive effect on the settlement rate.

Consider now the effect of adverse selection on the settlement rate. As discussed before, an increase in the latter provides the patent holder with incentives to increase the amount requested in the settlement offer. This leads to a lower settlement rate, and is consistent with the idea that an increase in adverse selection has generally a negative impact on efficiency.[29] This is why an increase (decrease) in adverse selection due to bifurcation, i.e. $\frac{A^b}{A^{nb}} > 1$ ($\frac{A^b}{A^{nb}} < 1$) has a negative (positive) effect on the ratio of settlement rates $\frac{\tilde{r}^b}{\tilde{r}^{nb}}$.

From the discussion above it follows that we need to distinguish again between the same two cases as before:

[29] In our context, reaching a settlement is an efficient outcome and an increase in the extent of adverse selection leads to a decrease in the probability of this event.

1 If $A^b \leq A^{nb}$ then bifurcation has a positive effect on the settlement rate: it increases the joint surplus from settlement and decreases the extent of adverse selection.
2 If $A^b > A^{nb}$ then bifurcation has an ambiguous effect on the settlement rate: it increases the joint surplus from settlement but also increases the extent of adverse selection.

Scenario 2: $\check{\theta}(c_D) \geq \overline{\theta}$ (or, equivalently, "high" c_D)

In this (other polar) simple scenario, the patent's validity is never challenged if the settlement attempt fails. We can therefore derive the equilibrium settlement amount $\tilde{S}^b$ and the corresponding probability threshold $\tilde{\theta}^b$ from the analysis of the non-bifurcated system by replacing α^{nb} with 1 in (3) and (4):

$$\tilde{S}^b = \begin{cases} L_D\overline{\theta} - C_P & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P}{L_D} \\ \underline{\theta} L_D + C_D & \text{otherwise} \end{cases}$$

and

$$\tilde{\theta}^b = \begin{cases} \overline{\theta} - \dfrac{C_P + C_D}{L_D} & \text{if} \quad \overline{\theta} - \underline{\theta} \geq \dfrac{C_D + C_P}{L_D} \\ \underline{\theta} & \text{otherwise} \end{cases}$$

For the sake of exposition, let us focus again on the set of parameters leading to interior solutions under both systems. In the current scenario, the extent of adverse selection under the bifurcated system is

$$A^b = L_D$$

and the joint surplus from settlement and the part of this surplus captured by the patent holder (gross of the settlement amount) are respectively given by

$$\Delta^b = C_P + C_D$$

and

$$\Delta_P^b = C_P$$

Comparing these with their counterparts under the non-bifurcated system shows that, in this scenario, bifurcation increases the extent of adverse selection ($A^b \geq A^{nb}$), decreases the joint surplus from settlement ($\Delta^b \leq \Delta^{nb}$), and decreases the part of the joint surplus from settlement captured by the patent holder ($\Delta_P^b \leq \Delta_P^{nb}$). Then, from (7) and (8) it follows that bifurcation leads unambiguously to an increase in the equilibrium settlement amount ($\tilde{S}^b \geq \tilde{S}^{nb}$) and a decrease in the settlement rate ($\tilde{r}^b \leq \tilde{r}^{nb}$). The reason for this finding is the same as in Scenario 1 (and so is the associated intuition): the settlement amount is positively affected by the extent of adverse selection and negatively affected by the part of the joint surplus from settlement captured by the patent holder (gross of the settlement amount), while the settlement rate is positively affected by the joint surplus from settlement and negatively affected by the extent of adverse selection.

The next proposition summarizes the results derived under the two scenarios considered above.

Proposition 3.

1. *If the additional cost of filing a validity challenge under the bifurcated system is sufficiently low ($\check{\theta}(c_D) < \underline{\theta}$) and bifurcation decreases the extent of adverse selection ($\alpha^b L_D + \left(1 - \alpha^b\right) l_D \leq \alpha^{nb} L_D$) then bifurcation has a negative effect on the settlement amount and a positive effect on the settlement rate.*
2. *If the additional cost of filing a validity challenge under the bifurcated system is sufficiently low ($\check{\theta}(c_D) < \underline{\theta}$), and bifurcation increases the extent of adverse selection ($\alpha^b L_D + \left(1 - \alpha^b\right) l_D > \alpha^{nb} L_D$) then bifurcation has an ambiguous effect on both the settlement amount and the settlement rate.*
3. *If the additional cost of filing a validity challenge under the bifurcated system is sufficiently high ($\check{\theta}(c_D) \geq \overline{\theta}$) then bifurcation has a positive effect on the settlement amount and a negative effect on the settlement rate.*

This proposition provides testable predictions and shows that the magnitude of the additional cost of filing a validity challenge under the bifurcated system can be (qualitatively) inferred from empirical findings about the effect of bifurcation on the settlement rate.

3.6. Extension: timing

In another extension, presented in online Appendix D, we consider a variant of our setting in which the timeline and, in particular, the injunction gap are explicitly modeled. We model the time that elapses between the actions of the following

(strategic and non-strategic) players: the court(s), the patent holder, the alleged infringer and a third firm that considers entering the market before the patent expires (but will only do so if the patent is invalidated).

If the court finds that the patent is valid and infringed, it makes the infringer pay damages to the patent holder. We suppose that these damages are equal to the loss incurred by the patent holder because the alleged infringer was active in the output market. Moreover, when the court finds the patent to be valid and infringed, it imposes an injunction against the alleged infringer who has then to stay out of the market until the patent expires.

Under the bifurcated system, if the patent is found invalid after being found infringed, the infringer can re-enter the market right after the invalidity decision. Moreover, he can recover the damages he had to pay to the patent holder after the judgment regarding the infringement issue, and can claim for compensation for the fact that he wrongly faced an injunction between the two court judgments. To capture the loss (benefit) that the injunction gap induces for the alleged infringer (patent holder) we assume that the alleged infringer is not fully compensated for the loss incurred between the two court judgments.

We show in online Appendix D that the patent holder's and alleged infringer's payoffs in this model are a special case of the reduced-form payoffs in our baseline model. On the one hand, this shows that all the results we derived in our basic setting carry over to this extension, and, on the other hand, it provides micro-foundations for the reduced-form payoffs of the baseline model.

4. Data

The focus of our empirical analysis is on the German bifurcated litigation system. However, our comparison of the bifurcated with the non-bifurcated system also relies on U.K. litigation data. In this section we discuss our data for both jurisdictions.

4.1. Data sources

Germany: regional courts – infringement

We collected data on infringement actions directly from the three regional courts that deal with the majority of patent infringement cases in Germany: the Regional Courts of Düsseldorf, Mannheim, and Munich I. We obtained detailed information on proceedings filed during the time period 2000–2008. This provides us with a nine-year window but also minimizes the number of cases that were still pending during the data collection.[30]

The information extracted for each case concerns procedural aspects, the identity of the litigants and their legal representatives, and the patents at issue. The data include information on the names and addresses of the plaintiffs and defendants, which allowed us to match corporate litigants to firm-level databases, including Bureau van Dijk's ORBIS, Compustat and THOMSON One.

With the patent application (or publication) numbers referenced in the case files, we retrieved detailed information on the litigated patents from EPO's Patstat.[31] Patstat provides us with detailed information on patent characteristics, such as application and publication dates, patent classes, etc. On basis of the patent numbers we constructed the respective patent families to obtain other European national as well as EP equivalents in order to identify cases where a particular patent dispute spreads across multiple national jurisdictions.

Germany: Federal Patent Court – invalidity

We also have information on invalidity proceedings before the BPatG and its appeal court, the BGH. Both courts publish all decisions on validity since 2000 on their websites. We also obtained information on the filing date as well as withdrawn actions in both instances from the register of the German Patent and Trademark Office. This allowed us to construct the course of the invalidity proceedings without having to access the case files at the courts.

U.K.: PHC and PCC/IPEC – infringement and invalidity

For the U.K., we have detailed data on the population of cases at the PHC, and the PCC/IPEC. Data for the PHC are available for the period 2000–2013, whereas no IPEC court records are available for cases filed prior to 2007.[32] The PHC and IPEC data

[30] Data collection started in Mannheim in spring 2010, in Munich in December 2010 and in Düsseldorf in December 2011. On average seven junior lawyers (*Referendare*) were employed as research assistants at each court to record the data directly from the dockets. Most research assistants had already passed the qualifying examination that authorizes them to practice law in Germany. They also received specific training for the data collection. Because case files are stored at the courts only in paper format, our research assistants had to digitize the relevant information directly at the regional courts. To retrieve all information in a systematic manner, we created a common data template. To address potential problems originating from pending cases, we revisited the court records at the Regional Court Düsseldorf in June 2013. In addition, over the past few years, German courts have increasingly made decisions available online. We repeatedly screened the online case repositories and complemented our records where possible. As a result, there are only 33 cases (<1%) in our dataset where the first instance infringement decision is still unknown to us and which we therefore drop from our sample.

[31] We use the Patstat version October 2015.

[32] Estimates based on anonymized data for 2005/06 suggest that cases at the PCC accounted for only around 20% of all patent cases in the U.K. during the 2000–2006 period (Cremers et al., 2016). Also, case counts at the PCC were very low in absolute terms compared to the period 2007–2013 for which we have data.

for the period 2007–2013 were collected directly from physical PHC and IPEC court records/files in 2014 and 2015.[33] The PHC data for the earlier 2000–2006 period were collected from a range of online sources.[34] The U.K. court records contain detailed information on both infringement claims and invalidity counterclaims, as well as case outcomes. As for the German data, we matched the names of the parties involved to firm-level databases (Bureau van Dijk's FAME, Amadeus, and Compustat) and retrieved detailed information from Patstat on the litigated patents.

EPO and DPMA – opposition

We have data on any prior or parallel opposition of the patents involved in an infringement action. For DE patents we have information on the opposition proceeding, i.e. the opposition's filing and end dates as well as outcome, from the register of the DPMA. We constructed data on oppositions at the EPO based on legal status information from Patstat covering 1981 to 2012. In contrast to the data from the DPMA, the data for oppositions at the EPO have information on the identity of the opponent, that is, the party filing the opposition. We added information on any opposition to the patents involved in an infringement proceeding to identify parallel invalidity proceedings in form of oppositions and to construct each patent's history of validity challenges.

4.2. Sample description

Germany

The patent litigation actions collected at the Regional Courts of Mannheim, Düsseldorf, and Munich cover around 90% of all patent infringement cases during the period 2000–2008.[35] We drop cases from our dataset that involve a patent, but that are not directly concerned with infringement.[36] We also drop cases involving utility models because the bifurcation principle only applies to invention patents. Furthermore, to avoid misinterpretation of case outcomes, we also remove a small number of negative declaratory actions and cases where the court decides only on issues regarding the enforcement of a previous judgment (e.g. the amount of damages granted). The resulting sample contains 3279 patent infringement cases. As some actions are filed on the basis of more than one patent, our sample contains 3600 patent-case observations.[37]

For the time period 2000 to 2008 our data count 1822 invalidity actions filed at the Federal Patent Court.[38]

U.K.

For the U.K., our data cover the population of patent cases between 2007 and 2013. For 2000–2006 we estimate that our data contain around 80% of disputes. As in the German data, we drop cases that are not directly concerned with infringement as well as those on negative declaratory actions. We also drop cases that are withdrawn or settled within 90 days counting from the filing date of the claim form as these cases are not relevant for our analysis.[39] The resulting sample contains 299 patent infringement cases involving 377 different patents. As several actions are filed on the basis of more than one patent, our sample contains 461 patent-case observations.

5. Effects of bifurcation

In this section, we first provide empirical evidence on the injunction gap in the bifurcated litigation system. We then analyze the likelihood of invalidity challenges and settlements in the bifurcated and non-bifurcated systems.

5.1. Divergent decisions

We begin by assessing the frequency of cases where a patent was 'invalid but infringed' in the German litigation system. Such decisions are only possible in systems that separate infringement and validity proceedings and depend on the temporal

[33] The data collection and assembly is described in detail in Helmers et al. (2015).

[34] To ensure completeness of our records, we relied on the Court Diary which lists all cases scheduled for a hearing or application, including a case management conference which is usually the first step in the litigation process. The data collection is described in detail in Helmers and McDonagh (2012).

[35] We estimate that roughly half of the remaining 10% of cases are spread over the other nine regional courts. However, these courts are of minor importance and reputation. The possibility to choose a litigation venue might create incentives for forum shopping (Gaessler, 2016). In our setting forum shopping might compound the effects of bifurcation, although it is unclear how important such an effect might be given the strong concentration of litigation activity in only three regional courts.

[36] This includes employee invention disputes, licensing and patent transfer disputes, as well as patent arrogations and false marking.

[37] For the empirical analysis in Section 5.2, we further exclude cases that end with a judgment in the first 120 days because they represent decisions on preliminary injunctions without a subsequent main proceeding. Since our focus lies on invalidity actions as a response to an infringement allegation, we also exclude cases with a pending opposition proceeding throughout the whole infringement case. For the empirical analysis in Section 5.3, the sample is further reduced by excluding cases that end in settlement after a validity challenge to remain consistent with our theoretical model.

[38] As parallel invalidity proceedings may be filed either before or after this time frame, we identified all invalidity actions filed against patents involved in an infringement proceeding and added these to our data. For more details and a breakdown of court cases by court see Cremers et al. (2016).

[39] These are generally cases where the defendant did not even file an initial defense, i.e. the only action that occurred is the filing of the claim form. This usually happens when a defendant does not respond at all to the case, the plaintiff simply drops the case, or the parties settle immediately after the filing of the claim form.

Table 1
Comparing outcomes of infringement and invalidity proceedings where infringement was decided first.

	Outcome parallel invalidity proceeding				
Outcome LG	valid	partly invalid	invalid	withdrawn	Total
infringed	58	50	55	133	296
	43.6%	23.9%	25.0%	19.4%	23.7%
partly infringed	21	21	19	51	112
	15.8%	10.0%	8.6%	7.4%	9.0%
not infringed	23	46	58	88	215
	17.3%	22.0%	26.4%	12.8%	17.2%
settlement	31	92	88	414	625
	23.3%	44.0%	40.0%	60.3%	50.1%
Total	133	209	220	686	1248
	100.0%	100.0%	100.0%	100.0%	100.0%

Notes: Dark gray-shaded area shows clear divergent decisions. Light gray-shaded area shows presumed divergent decisions. The sample consists of all infringement proceedings with a parallel invalidity proceeding and where the first instance infringement outcome is first. In case of multiple invalidity decisions, the fastest decision is chosen. The unit of observation is at the patent in the infringement proceedings.

spread between infringement and validity challenges. Fig. A-3 in the online appendix shows that in most cases the invalidity action followed its corresponding infringement action. As invalidity proceedings take on average longer, too (see Fig. A-4 in the online appendix), the infringement decision is usually handed down first, despite the possibility to have the infringement proceeding stayed. The (first instance) decision on validity is taken on average 6.8 months *after* the (first instance) decision on infringement. This shows that there is substantial scope for an injunction gap: if a patent is found to be infringed, the patent holder has on average 6.8 months to enforce the patent even if the patent is invalidated once the BPatG (invalidity) or DPMA and EPO (opposition) hand down their decision.

Table 1 cross-tabulates the (first instance) infringement and invalidity outcomes for all 1248 parallel cases where the decision on infringement was handed down first. The gray-shaded cells in Table 1 show that there is a sizeable number of cases where the patent was first found to be infringed and later invalidated by the BPatG or the DPMA/EPO. If we also consider cases where the patent was partly invalidated or infringed, there is a total of 145 cases. For comparison, in only 69 cases patents that were found to be (partly) infringed were upheld in the invalidity proceeding. This means that slightly more than 11.6% of cases (including cases that settled) produce divergent decisions – the patent is first found to be infringed but later invalidated.[40] If we focus on cases with a decision in both venues, the share increases to 41.3%.

Fig. 2 shows the length of the injunction gap for the 145 cases with divergent decisions. The figure distinguishes between invalidity decisions through the opposition divisions of the DPMA/EPO and the BPatG. The median injunction gap for cases in which the infringed patent was eventually invalidated by the BPatG is about 14 months. Hence, parties that have won the infringement case have little over a year to enforce a patent that should not have been granted in the first place.[41] The length of the injunction gap is significantly longer for cases in which the patent was invalidated through opposition procedures. The median is 34 months. As shown in Fig. 2, the main reason for this is that there are a considerable number of opposition proceedings that take a lot longer to reach a final decision than invalidity proceedings at the BPatG.

As explained in Section 2, the judgment by the infringement court is (preliminarily) enforceable despite a pending decision on validity. The only way to prevent an injunction from taking binding effect is to appeal the judgment. In fact, we observe an appeal rate of 57.9% for cases with a parallel invalidity proceeding compared to 26.2% for cases with no parallel invalidity proceeding.[42] An assessment of final outcomes of cases with divergent decisions (Table A-2 in the online appendix) reveals that in 42.8% of cases with divergent decisions in first instance, the divergent decision is upheld upon appeal.

Table 2 shows a comparison of case-, litigant-, and patent-level characteristics between defendants in infringement cases that were subject to divergent decisions and all other cases with 'non-divergent' outcomes. The litigation value does not differ significantly between divergent and non-divergent decisions, that is, there is no evidence for disproportionately many low-value cases ending up in an injunction gap. That said, we find that validity challenges in cases with divergent decisions are filed on average three months later than in cases with non-divergent decisions. This shows that the temporal separation of infringement and invalidity proceedings contributes to divergent outcomes. When we look at the size of the defendants in the infringement cases in the two groups, we find slightly more small firms in the divergent decision group on the one hand, and more large firms in the non-divergent decision group on the other.

[40] Fig. A-5 in the online appendix shows the occurrence of divergent decisions over time.
[41] Considering that appellate invalidity proceedings take several years, the actual injunction gap until the decision on the patent's invalidity is binding may be considerably longer.
[42] This hints at the possibility that the appeal rate is higher in a bifurcated system than in a non-bifurcated system. An appeal to an infringement decision may be useful – regardless of its prospects of success – in order to delay an injunction while the decision on validity is still pending.

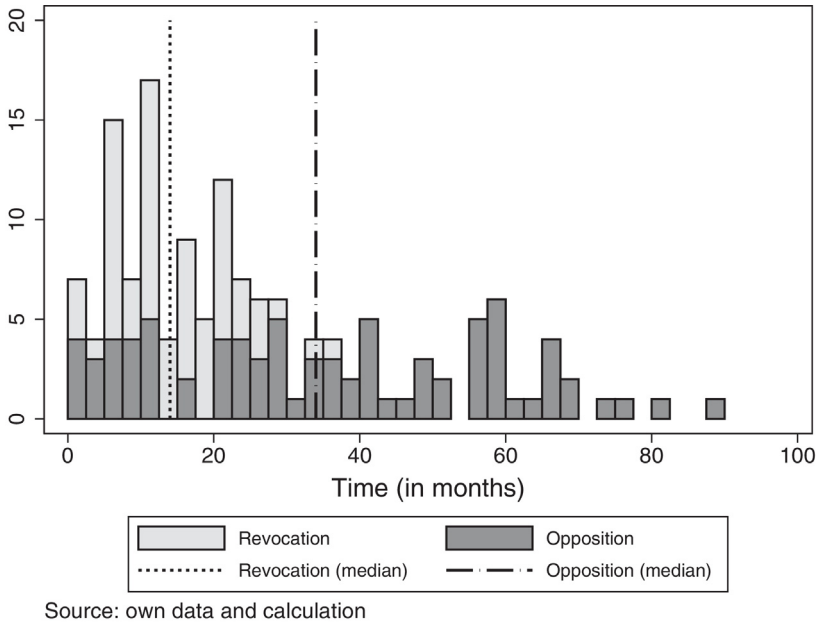

Fig. 2. Length of injunction gap for divergent decisions. Notes: The figure shows all divergent decisions regardless of whether parties have (preliminarily) enforced the infringement judgment.

Table 2
Comparison of alleged infringers by decision.

Variables	Decision type		SE mean diff.	Signif.
	Non-divergent Mean	Divergent Mean		
Alleged infringer				
Micro	0.11	0.12	0.028	
Small	0.15	0.23	0.032	**
Medium	0.21	0.27	0.037	
Large	0.52	0.39	0.044	***
Germany	0.82	0.88	0.033	*
Europe (excl. Germany)	0.13	0.10	0.029	
World (excl. Europe)	0.05	0.02	0.019	*
Top legal representative	0.55	0.61	0.044	
Proceeding				
Litigation value (in €)	1133.44	986.43	229.887	
Lag of invalidity action (in months)	4.14	6.57	0.916	***
Lag of opposition (in months)	−6.70	−6.53	1.535	
Technological area				
Electrical engineering	0.30	0.14	0.039	***
Instruments	0.12	0.20	0.029	***
Chemistry	0.15	0.23	0.033	**
Mechanical engineering	0.29	0.30	0.040	
Other	0.14	0.13	0.031	
Observations	1102	145		

Notes: The sample consists of all infringement proceedings with parallel invalidity proceedings or oppositions regardless of the timing of the decisions. The unit of observation is at the patent in each infringement proceeding.

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

5.2. Validity challenges

About 37.8% of infringement cases (counted at the patent-level) in Germany are associated with an invalidity action. This figure is low compared to litigation systems where infringement and invalidity are decided simultaneously in the same proceeding. In fact, in the U.K. we find counterclaims for invalidity in 71.6% of infringement cases. Table A-4 in the online appendix shows the share of infringement cases where validity was challenged and breaks it down by technology area of

Table 3
Probit model results: incidence of invalidity action (DE).

	(1)		(2)		(3)		(4)	
	Validity challenge		Validity challenge		Validity challenge		Validity challenge	
Alleged infringer								
Small (d)	0.066	(0.044)	0.042	(0.045)	0.038	(0.045)	0.036	(0.045)
Medium (d)	0.101**	(0.040)	0.080*	(0.041)	0.077*	(0.042)	0.075*	(0.042)
Large (d)	0.167***	(0.037)	0.134***	(0.039)	0.131***	(0.039)	0.110***	(0.040)
Europe (excl. Germany) (d)			−0.100***	(0.026)	−0.094***	(0.026)	−0.083***	(0.027)
World (excl. Europe) (d)			−0.223***	(0.040)	−0.227***	(0.039)	−0.207***	(0.041)
Number of parties							−0.004	(0.021)
Multinational group (d)							0.106***	(0.037)
Top legal representative (d)							0.148***	(0.022)
Patent holder								
Non-practicing entity (d)			−0.043	(0.038)	−0.035	(0.038)	−0.029	(0.039)
Small (d)			−0.011	(0.049)	−0.009	(0.049)	−0.013	(0.050)
Medium (d)			−0.033	(0.046)	−0.021	(0.047)	−0.023	(0.047)
Large (d)			−0.009	(0.044)	−0.002	(0.044)	−0.015	(0.044)
Europe (excl. Germany) (d)			0.032	(0.028)	0.040	(0.028)	0.026	(0.028)
World (excl. Europe) (d)			−0.060*	(0.035)	−0.056	(0.035)	−0.056	(0.035)
Top legal representative (d)							0.006	(0.028)
Invalidity history								
Patent solidified (opp. proc.) (d)					0.051*	(0.029)	0.039	(0.030)
Patent challenged (rev. proc.) (d)					−0.146***	(0.039)	−0.129***	(0.041)
Patent solidified (rev. proc.) (d)					−0.022	(0.080)	−0.040	(0.081)
Proceeding								
Parallel opposition proceeding (d)			−0.231***	(0.033)	−0.231***	(0.033)	−0.243***	(0.032)
Litigation value (in €, log)			0.046***	(0.011)	0.044***	(0.011)	0.039***	(0.011)
Multi-jurisdictional litigation (d)							0.091	(0.062)
Controls								
Year effects	Yes		Yes		Yes		Yes	
Technology effects	Yes		Yes		Yes		Yes	
Court effects	No		Yes		Yes		Yes	
Patent characteristics	Yes		Yes		Yes		Yes	
Pseudo R^2	0.041		0.079		0.079		0.099	
Observations	2529		2529		2529		2529	

Marginal effects reported; case-clustered standard errors in parentheses;
(d) for discrete change of dummy variable from 0 to 1.
Notes: The sample consists of all infringement proceedings without judgment/settlement during the first 120 days counting from the filing date of the case. The dependent variable is equal to one if the defendant challenged validity in parallel proceedings at the BPatG. The unit of observation is at the patent-case-level. Baseline litigant size: *micro*. Baseline litigant residence: *Germany*. Patent characteristics not reported in the table include patent age (in years), patent age (in years, squared), patent and non-patent backward citations, forward citations (in first 3 years), number of International Patent Classification (IPC) subclasses, patent family size, grant lag (diff. from mean in months), indicators for international PCT applications, EP patents, and accelerated examination. Technology effects include indicators for each main technology area (electrical engineering, instruments, chemistry, mechanical engineering, other). Court effects include indicators for each regional court.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

the patent in question. The rate of validity challenges is consistently nearly twice as large in the U.K. as it is in Germany across all technology areas.

The model in Section 3 suggested that in a bifurcated system alleged infringers are less likely to challenge validity due to the possibility of an injunction gap and the additional cost of initiating and conducting separate invalidity proceedings. To test Prediction 1 empirically, we compare directly the propensity that an alleged infringer files an invalidity action in Germany vs. the U.K. The model also predicted that in a bifurcated system, in particular more resource-constrained firms are less likely to contest validity. To test Prediction 2, we distinguish between four size categories: micro, small, medium and large.[43] We ask whether micro-sized corporate and individual defendants are less likely to challenge validity at the BPatG and compare this with the U.K. We estimate the following discrete choice specification:

$$inval_{pit} = \alpha_0 + \beta uk_{pit} + \sum_s \gamma_s size_{it} + \sum_s \delta_s [size_{it} \times uk_{pit}] + \theta X_{pit} + \sum_t \eta_t D_t + \epsilon_{pit} \quad (9)$$

[43] The size categories are defined according to the EU definition, which relies on information on a firm's number of employees, turnover, and total assets.

Table 4
Probit model results: incidence of validity challenges (DE-U.K. comparison).

	(1) DE only Validity challenge		(2) U.K. only Validity challenge		(3) DE+U.K. Validity challenge		(4) DE+U.K. Validity challenge	
Jurisdiction								
UK (d)					0.581***	(0.046)	0.551***	(0.082)
Alleged infringer								
Small (d)	0.035	(0.044)	−0.164	(0.138)	0.026	(0.042)	0.036	(0.045)
Medium (d)	0.078*	(0.041)	0.010	(0.102)	0.073*	(0.040)	0.081*	(0.042)
Large (d)	0.116***	(0.039)	−0.027	(0.078)	0.116***	(0.037)	0.121***	(0.040)
Europe (excl. Germany) (d)	−0.099***	(0.026)	0.178***	(0.041)	−0.091***	(0.027)	−0.099***	(0.027)
World (excl. Europe) (d)	−0.209***	(0.041)	−0.468**	(0.196)	−0.251***	(0.039)	−0.227***	(0.046)
Top legal representative (d)	0.157***	(0.022)	0.003	(0.061)	0.148***	(0.022)	0.150***	(0.022)
Alleged infringer × U.K.								
Small (d)							−0.205**	(0.098)
Medium (d)							−0.015	(0.152)
Large (d)							−0.079	(0.106)
Europe (excl. domestic) (d)							0.350**	(0.158)
World (excl. Europe) (d)							−0.206*	(0.117)
Patent holder								
Non-practicing entity (d)	−0.031	(0.038)	−0.178	(0.109)	−0.029	(0.037)	−0.048	(0.038)
Small (d)	−0.014	(0.049)	0.041	(0.094)	0.019	(0.048)	−0.013	(0.050)
Medium (d)	−0.034	(0.046)	0.149***	(0.057)	−0.004	(0.045)	−0.041	(0.047)
Large (d)	−0.016	(0.044)	0.334***	(0.119)	0.013	(0.041)	−0.020	(0.044)
Europe (excl. Germany) (d)	0.025	(0.028)	−0.257**	(0.102)	0.014	(0.027)	0.033	(0.029)
World (excl. Europe) (d)	−0.049	(0.035)	0.063	(0.079)	−0.024	(0.034)	−0.042	(0.036)
Top legal representative (d)	0.005	(0.028)	−0.222***	(0.074)	−0.016	(0.027)	−0.014	(0.028)
Patent holder × U.K.								
Small (d)							0.219	(0.170)
Medium (d)							0.375***	(0.132)
Large (d)							0.285**	(0.118)
Europe (excl. domestic) (d)						−0.264***	(0.061)	
World (excl. Europe) (d)							0.098	(0.125)
Invalidity history								
Patent solidified (opp. proc.) (d)	0.041	(0.029)	0.046	(0.085)	0.053*	(0.030)	0.055*	(0.030)
Proceeding								
Parallel opposition proceeding (d)	−0.231***	(0.034)	0.137***	(0.048)	−0.170***	(0.036)	−0.175***	(0.037)
Litigation value (in €, log)	0.042***	(0.011)	−0.005	(0.031)	0.037***	(0.010)	0.040***	(0.011)
Controls								
Year effects	Yes		Yes		Yes		Yes	
Technology effects	Yes		Yes		Yes		Yes	
Court effects	Yes		Yes		Yes		Yes	
Patent characteristics	Yes		Yes		Yes		Yes	
Pseudo R^2	0.091		0.391		0.123		0.131	
Observations	2529		461		2990		2990	

Marginal effects reported; standard errors in parentheses;
(d) for discrete change of dummy variable from 0 to 1.
Notes: The DE (U.K.) sample consists of all infringement proceedings without settlement/judgment during the first 120 (90) days counting from the filing date of the case. The dependent variable is equal to one if the defendant challenged validity – DE: in parallel proceedings at the BPatG – U.K.: through an invalidity counterclaim in the same proceedings. The unit of observation is at the patent-case-level. U.K. cases with multiple patents are weighted to account for oversampling. Baseline litigant size: *micro*. Baseline litigant residence: *domestic* (Germany/U.K.). Patent characteristics not reported in the table include patent age (in years), patent age (in years, squared), patent and non-patent backward citations, forward citations (in first 3 years), number of International Patent Classification (IPC) subclasses, patent family size, grant lag (diff. from mean in months), indicators for international PCT applications, EP patents, and accelerated examination. Technology effects include indicators for each main technology area (electrical engineering, instruments, chemistry, mechanical engineering, other). Court effects include indicators for each German and U.K. court.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

where $inval_{pit}$ is a dummy variable that is equal to one if the alleged infringer i challenged validity of patent p in year t. uk_{pit} denotes a dummy variable that is equal to one if a case was litigated in the U.K., $size_{it}$ are three dummy variables for the different company size categories (small, medium, and large) where the omitted category is micro-sized firms. $size_{it} \times uk_{pit}$ is the interaction of size categories and the U.K. dummy variable. The specification includes a number of patent-, case-, and litigant-characteristics among the regressors X_{pit} (for a detailed definition of these variables see online Appendix E).

The regressions also include year, patent technology class, and court dummies. We estimate the specification in (9) using a probit model and cluster standard errors at the case-level. Summary statistics are shown in Table A-3 in the online appendix.

Table 3 shows the results when we focus on patent cases in Germany. As we move from left (column 1) to right (column 4), we add additional variables at the defendant-, plaintiff-, patent-, and case-level. All specifications include year and technology effects and a number of patent characteristics. The results for our preferred specification in column 4 show that medium-sized and large firms are about 7% and 11% respectively more likely to file an invalidity action at the BPatG than micro-sized alleged infringers. This suggests that smaller defendants in infringement proceedings are less likely to challenge the validity of the patent at issue. In contrast, there is no evidence that the size of the plaintiff in the infringement proceedings, that is the patent holder, plays any role in the decision to challenge the patent's validity. This supports the view (and Prediction 2 of our model) that the decision *not* to file a parallel action at the BPatG is at least partly determined by resource constraints on the alleged infringer's side.

Next, we turn to our cross-jurisdictional comparison of the incidence of a separate invalidity action at the BPatG in Germany with that of an invalidity counterclaim in the U.K. Columns 1 and 2 in Table 4 show the results for Germany and the U.K. individually (the specification differs slightly form that used in Table 3 because a number of variables are not available in the U.K. dataset).[44] The estimates for the U.K. shown in Column 2 indicate that there is no statistically significant difference in the propensity to challenge validity through a counterclaim across firms in the different size groups in the U.K. Micro-sized companies are no less likely to challenge validity than firms in any of the other three size categories (see also Table A-4 in the online appendix for descriptive evidence). In columns 3 and 4 we pool the German and U.K. data to estimate specification (9). First, the U.K. dummy variable is statistically highly significant, positive, and large in magnitude. This clearly indicates that alleged infringers are more likely (around 55%) to challenge validity in infringement proceedings in the non-bifurcated relative to the bifurcated system. This confirms Prediction 1 of our theoretical model. Moreover, when we look at the interaction of the U.K. dummy with the firm-size dummies, we see that the signs are all negative and in case of the small company size category even statistically significant. This confirms the findings from column 2 that micro-sized companies are not less likely to challenge validity in the U.K. as opposed to the German bifurcated system adding further evidence in support of Prediction 2.

The results in Tables 3 and 4, therefore, provide strong evidence in favor of a 'validity-challenge deterrence' effect of bifurcation as suggested by our model. Alleged infringers are generally less likely to challenge validity in the bifurcated system compared to the non-bifurcated system. Moreover, more resource-constrained firms are less likely to file an invalidity action in response to an infringement claim in the bifurcated system. This also implies that the 11.6% of 'invalid but infringed' cases shown in Section 5.1 in the German system are downward biased. Fewer patents are in fact invalidated than in the absence of the additional costs engendered by bifurcation. This also contributes to the strong presumption of validity in a litigation system where infringement is decided first in a self-reinforcing way.

5.3. Settlement

The extension of our model looked at the impact of bifurcation on settlement amounts and rates. Settlement amounts are private information and usually not disclosed in court records. Hence we focus on the incidence of settlements, which observe in our data. The model in Section 3.5 produced ambiguous predictions regarding the propensity to settle in a bifurcated system compared to the non-bifurcated system (Proposition 3). Hence, we rely on the data to reveal which one of the different effects of bifurcation dominates. To do this, we again compare directly the outcomes of infringement cases in Germany with the U.K. We also test for differences in settlement behavior across firm-size groups because our model suggests that the additional costs involved in a validity challenge in the bifurcated system are one of the determinants of settlements. Hence, we estimate the analogue to specification (9):

$$settle_{pit} = \alpha_0 + \beta uk_{pit} + \sum_s \gamma_s size_{it} + \sum_s \delta_s [size_{it} \times uk_{pit}] + \theta X_{pit} + \sum_t \eta_t D_t + \epsilon_{pit} \tag{10}$$

where $settle_{pit}$ is a dummy variable that is equal to one if the case was settled. Note that our sample of cases has changed compared to specification (9), because we drop all cases that settled *after* an invalidity action was filed. Following the structure of our theoretical model, we are interested in the incidence of settlement before the defendant decides to challenge validity. All other variables remain unaltered compared to specification (9). We also estimate the specification in (10) using a probit model and cluster standard errors at the case-level. Summary statistics are shown in Table A-3 in the online appendix.

Table 5 shows the results for Germany. The estimates show that all marginal effects for the set of size dummies are positive and statistically significantly different from zero in the case of medium-sized and large firms, although in the latter case only marginally so in column 4. This indicates that smaller companies are less likely to settle compared to larger companies.

Turning to the comparison between Germany and the U.K. in Table 6, we find first of all in columns 3 and 4 a statistically highly significant and negative marginal effect for the U.K. dummy variable, which means that parties have a lower propensity to settle in the U.K. This empirical finding is in line with the theoretical predictions derived under Scenario 1 (i.e. "low" c_D)

[44] Alternative specifications for the U.K. can be found in Table A-5 in the online appendix.

Table 5
Probit model results: incidence of settlement (DE).

	(1) Case settled		(2) Case settled		(3) Case settled		(4) Case settled	
Alleged infringer								
Small (d)	0.039	(0.047)	0.056	(0.048)	0.057	(0.048)	0.052	(0.048)
Medium (d)	0.089*	(0.043)	0.117**	(0.045)	0.116**	(0.045)	0.117**	(0.045)
Large (d)	0.028	(0.040)	0.073	(0.043)	0.072	(0.044)	0.088*	(0.044)
Europe (excl. Germany) (d)			0.208***	(0.031)	0.205***	(0.031)	0.195***	(0.032)
World (excl. Europe) (d)			0.051	(0.057)	0.056	(0.058)	0.021	(0.058)
Number of parties							−0.047	(0.033)
Multinational group (d)							−0.098*	(0.045)
Top legal representative (d)							−0.145***	(0.025)
Patent holder								
Non-practicing entity (d)			0.108*	(0.048)	0.105*	(0.048)	0.087	(0.048)
Small (d)			0.117*	(0.059)	0.116*	(0.059)	0.105	(0.059)
Medium (d)			0.061	(0.057)	0.055	(0.057)	0.050	(0.057)
Large (d)			0.068	(0.052)	0.065	(0.052)	0.063	(0.051)
Europe (excl. Germany) (d)			0.035	(0.032)	0.030	(0.032)	0.042	(0.033)
World (excl. Europe) (d)			0.120**	(0.039)	0.118**	(0.040)	0.110**	(0.040)
Top legal representative (d)							0.027	(0.033)
Invalidity history								
Patent solidified (opp. proc.) (d)					−0.032	(0.034)	−0.013	(0.035)
Patent challenged (rev. proc.) (d)					0.055	(0.060)	0.045	(0.059)
Patent solidified (rev. proc.) (d)					0.031	(0.092)	0.043	(0.093)
Proceeding								
Parallel opposition proceeding (d)			0.240***	(0.054)	0.238***	(0.055)	0.247***	(0.056)
Litigation value (in €, log)			−0.026*	(0.012)	−0.026*	(0.012)	−0.022	(0.012)
Multi-jurisdictional litigation (d)							0.095	(0.072)
Controls								
Year effects	Yes		Yes		Yes		Yes	
Technology effects	Yes		Yes		Yes		Yes	
Court effects	No		Yes		Yes		Yes	
Patent characteristics	Yes		Yes		Yes		Yes	
Pseudo R^2	0.067		0.104		0.106		0.122	
Observations	2020		2020		2020		2020	

Marginal effects reported; standard errors in parentheses;
(d) for discrete change of dummy variable from 0 to 1
Notes: The sample consists of all infringement proceedings without judgment during the first 120 days or settlement after the filing of an invalidity action. The dependent variable is equal to one if the case settled. The unit of observation is at the patent-case level. Cases with multiple patents are weighted to account for oversampling. Baseline litigant size: *micro*. Baseline litigant residence: *Germany*. Patent characteristics not reported in the table include patent age (in years), patent age (in years, squared), patent and non-patent backward citations, forward citations (in first 3 years), number of number of International Patent Classification (IPC) subclasses, patent family size, grant lag (diff. from mean in months), indicators for international PCT applications, EP patents, and accelerated examination. Technology effects include indicators for each main technology area (electrical engineering, instruments, chemistry, mechanical engineering, other). Court effects include indicators for each regional court.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

and is inconsistent with those derived under Scenario 2 (i.e. "high" c_D). The fact that our empirical analysis rejects Scenario 2 is not surprising since, in that scenario, the additional cost of filing a validity challenge under the bifurcated system is sufficiently high for all validity challenges to be deterred, which is not consistent with our data.

When we look at the marginal effects of the size dummies for the U.K. sample in column 2, we find that the marginal effects of none of the size dummies are remotely statistically significant (for more results for the U.K. sample see Table A-6 in the online appendix). That is, there is no evidence that settlement behavior differs in the U.K. across firms of different size which corroborates our findings from our analysis of the incidence of invalidity challenges: the additional cost of filing an invalidity action is less important in the U.K. and hence does not affect smaller firms disproportionately more. When we look at the pooled sample in columns 3 and 4, the marginal effects of the U.K.-size interaction terms for the alleged infringer are not statistically significant while the medium and large firm size dummies on their own still are significant. Hence, we see that in the U.K. (a) infringement cases are less likely to settle than in Germany and (b) smaller firms are equally likely to settle as larger firms while in Germany smaller firms are less likely to settle. These two findings in combination imply that the pattern of settlement rates in Germany can at least partly be attributed to the additional cost of filing a validity challenge in the bifurcated system.

Table 6
Probit model results: incidence of settlement (DE-U.K. comparison).

	(1) DE only Case settled		(2) U.K. only Case settled		(3) DE + U.K. Case settled		(4) DE + U.K. Case settled	
Jurisdiction								
U.K. (d)					−0.391***	(0.049)	−0.303***	(0.116)
Alleged infringer								
Small (d)	0.051	(0.048)	0.251	(0.179)	0.048	(0.046)	0.053	(0.047)
Medium (d)	0.118***	(0.045)	0.226	(0.209)	0.107**	(0.043)	0.115***	(0.044)
Large (d)	0.079*	(0.044)	-0.011	(0.107)	0.054	(0.042)	0.078*	(0.043)
Europe (excl. Germany) (d)	0.209***	(0.031)	−0.179**	(0.082)	0.185***	(0.031)	0.201***	(0.031)
World (excl. Europe) (d)	0.038	(0.058)	0.304	(0.190)	0.072	(0.055)	0.042	(0.057)
Top legal representative (d)	−0.149***	(0.025)	0.073	(0.095)	−0.132***	(0.024)	−0.135***	(0.024)
Alleged infringer × U.K.								
Small (d)							0.228	(0.182)
Medium (d)							0.034	(0.217)
Large (d)							−0.168	(0.125)
Europe (excl. domestic) (d)							−0.375***	(0.052)
World (excl. Europe) (d)							0.261	(0.169)
Patent holder								
Non-practicing entity (d)	0.090*	(0.048)	−0.089	(0.087)	0.060	(0.045)	0.078*	(0.045)
Small (d)	0.111*	(0.059)	−0.163	(0.102)	0.067	(0.055)	0.099*	(0.057)
Medium (d)	0.060	(0.057)	−0.148	(0.137)	0.011	(0.053)	0.045	(0.055)
Large (d)	0.067	(0.051)	−0.123	(0.137)	0.027	(0.047)	0.053	(0.049)
Europe (excl. Germany) (d)	0.045	(0.033)	0.126	(0.109)	0.049	(0.030)	0.037	(0.032)
World (excl. Europe) (d)	0.111***	(0.040)	−0.044	(0.100)	0.088**	(0.037)	0.103***	(0.039)
Top legal representative (d)	0.029	(0.032)	0.021	(0.079)	0.026	(0.030)	0.025	(0.030)
Patent holder × U.K.								
Small (d)							−0.258*	(0.145)
Medium (d)							−0.309**	(0.122)
Large (d)							−0.182	(0.125)
Europe (excl. domestic) (d)							0.263**	(0.125)
World (excl. Europe) (d)							−0.103	(0.137)
Invalidity history								
Patent solidified (opp. proc.) (d)	−0.017	(0.035)	−0.113	(0.088)	−0.022	(0.033)	−0.026	(0.033)
Proceeding								
Parallel opposition proceeding (d)	0.245***	(0.056)	−0.221***	(0.053)	0.164***	(0.051)	0.165***	(0.053)
Litigation value (in €, log)	−0.022*	(0.012)	0.070***	(0.024)	−0.008	(0.011)	−0.015	(0.012)
Controls								
Year effects	Yes		No		Yes		Yes	
Technology effects	Yes		Yes		Yes		Yes	
Court effects	Yes		Yes		Yes		Yes	
Patent characteristics	Yes		Yes		Yes		Yes	
Pseudo R^2	0.119		0.316		0.115		0.125	
Observations	2020		287		2307		2307	

Marginal effects reported; standard errors in parentheses;
(d) for discrete change of dummy variable from 0 to 1
Notes: The DE sample consists of all infringement proceedings without judgment during the first 120 days or settlement after the filing of an invalidity action. The U.K. sample consists of all infringement proceedings without settlement after the filing of a validity challenge counter-claim. The dependent variable is equal to one if the case settled. The unit of observation is at the patent-case-level. Cases with multiple patents are weighted to account for oversampling. Baseline litigant size: *micro*. Baseline litigant residence: *domestic* (Germany/U.K.). Patent characteristics not reported in the table include patent age (in years), patent age (in years, squared), patent and non-patent backward citations, forward citations (in first 3 years), number of International Patent Classification (IPC) subclasses, patent family size, grant lag (diff. from mean in months), indicators for international PCT applications, EP patents, and accelerated examination. Technology effects include indicators for each main technology area (electrical engineering, instruments, chemistry, mechanical engineering, other). Court effects include indicators for each German and U.K. court.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

6. Conclusion

Proponents of bifurcation argue that exclusive jurisdiction over patent validity offers the advantage of specialization which should result in more legal certainty regarding the validity of patents. The flipside of bifurcation is that it requires additional cost for a validity challenge compared to a non-bifurcated system. Perhaps more surprisingly, our empirical analysis also shows that bifurcation can generate additional costs for alleged infringers (and benefits for patent holders) due

to the relatively frequent occurrence of an injunction gap. Our theoretical analysis shows that if we take these various effects of bifurcation into account, the theoretical predictions are less clearcut than what one might have expected. That is, *ex ante* it is in fact unclear whether the non-bifurcated system is preferable over the bifurcated system. We find that the impact of bifurcation on the patent holder's propensity to sue for infringement is ambiguous; the impact of bifurcation on both settlement amounts and rates is also ambiguous. Nevertheless, the theory offers one clear prediction: bifurcation results in a 'validity-challenge deterrence' effect.

Our empirical analysis sheds more light on the comparison of bifurcated and non-bifurcated systems. We find strong evidence that alleged infringers are less likely to challenge the validity of an allegedly infringed patent in the bifurcated system everything else equal. Since this effect is driven by the additional cost of filing and pursuing an invalidity claim at a separate court, this effect affects smaller, more resource-constrained companies more. Our data do not permit us to analyze the impact of this 'validity-challenge deterrence' effect on innovative activities, but it is possible that this effect dampens incentives to innovate in particular among smaller firms. The lower likelihood of facing an invalidity challenge might also increase the incentives to obtain and enforce weak patents. We do not investigate such strategic effects of bifurcation here, but this is certainly a topic that deserves further scrutiny.

Our empirical analysis also reveals that parties are more likely to settle in a bifurcated system. This means that, for a given level of litigation intensity, litigation costs are probably lower under a bifurcated system. However, a higher settlement rate also implies that the uncertainty over the scope and validity of patents may be higher under a bifurcated system, which may lead to a higher litigation intensity.[45] Finally, a bifurcated system arguably generates higher administrative costs compared to a non-bifurcated system. From this perspective, training and appointing judges with a technical background while maintaining a unified court may be superior to using a bifurcated system.

Appendix A. Supplementary data

Online Appendix associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2016.08.005.

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